PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2001-064099
(43)Date of publication of application : 13.03.2001

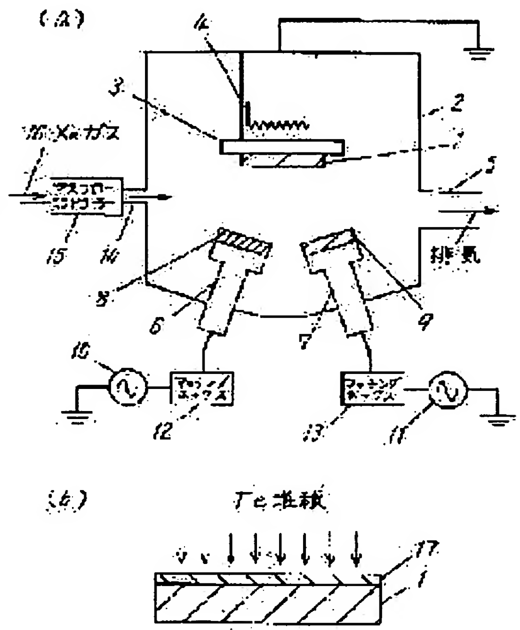
(51)Int.CI. C30B 29/52
C30B 25/06
H01L 21/203
H01L 31/04

(21)Application number : 11-239343
(22)Date of filing : 26.08.1999

(71)Applicant : MATSUSHITA ELECTRONICS INDUSTRY CORP
(72)Inventor : TAMURA AKIYOSHI

(54) THIN FILM FORMATION

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a film forming method for forming a high quality β-$FeSi_2$ epitaxial layer on an Si-substrate.
SOLUTION: A β-FeSi2 layer 17 is formed by arranging an n-type Si-substrate 1 of the (100) plane on a substrate holder 3 provided in a vacuum chamber 2 of a magnetron sputtering device and then depositing Fe on the Si-substrate 1 by sputtering using gaseous Xe as the sputtering gas while heating the substrate so as to keep its temp. at 550 to 650°C. Gaseous Xe has large mass in comparison with gaseous Ar being generally used in sputtering. Therefore, when Fe is deposited by sputtering, the dissociation of the Si-Si bond at the surface of the Si-substrate proceeds efficiently, and the reaction of Si and deposited Fe is accelerated by exposing the surface of the Si-substrate to the plasma gas of Xe, thereby the high quality β-FeSi2 epitaxial layer can be formed.



LEGAL STATUS
[Date of request for examination]
[Date of sending the examiner's decision of rejection]
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]
[Date of final disposal for application]
[Patent number]
[Date of registration]
[Number of appeal against examiner's decision of rejection]

Best Available Copy

* NOTICES *

JPO and NCIPI are not responsible for any damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

CLAIMS

[Claim(s)]
[Claim 1] The formation approach of the thin film characterized by depositing iron on the heated silicon substrate using the spatter which used krypton gas or xenon gas, and forming a beta iron silicide layer on said silicon substrate by the reaction with the silicon of said silicon substrate.
[Claim 2] The formation approach of the thin film characterized by depositing iron and silicon coincidence or by turns on the heated silicon substrate using the spatter which used krypton gas or xenon gas, and forming a beta iron silicide layer on said silicon substrate.
[Claim 3] The formation approach of the thin film which deposits iron in the state of an anion on the heated silicon substrate, and is characterized by forming a beta iron silicide layer on said silicon substrate by the reaction with the silicon of said silicon substrate.
[Claim 4] The formation approach of the thin film which deposits iron on the heated silicon substrate and is characterized by including the process which irradiates the radical ion of hydrogen or rare gas by turns simultaneous in iron deposition on said silicon substrate by the reaction with the silicon of said silicon substrate in the process which forms a beta iron silicide layer on said silicon substrate.
[Claim 5] The formation approach of the thin film characterized by depositing iron and silicon on the heated silicon substrate at coincidence, and irradiating the radical ion of hydrogen or rare gas by turns simultaneous in deposition of iron and silicon in the process which forms a beta iron silicide layer on said silicon substrate.
[Claim 6] The formation approach of a thin film according to claim 4 or 5 that rare gas is characterized by including one component of neon, an argon, a krypton, and a xenon.
[Claim 7] The formation approach of the thin film according to claim 4 or 5 characterized by depositing iron in the state of an anion.
[Claim 8] The formation approach of the thin film according to claim 1 to 5 characterized by heating a silicon substrate in 400-700 degrees C.
[Claim 9] The formation approach of the thin film which deposits iron, heating said silicon substrate and is characterized by forming a beta iron silicide layer by the reaction with the silicon of said silicon substrate after carrying out the ion implantation of iron or the silicon to a silicon substrate surface.
[Claim 10] The formation approach of the thin film which deposits iron and is characterized by forming a beta iron silicide layer by the reaction with the silicon of said silicon substrate while heating said silicon substrate after carrying out the ion implantation of the rare gas to a silicon substrate surface.
[Claim 11] The formation approach of a thin film according to claim 10 that rare gas is characterized by including one component of neon, an argon, a krypton, and a xenon.
[Claim 12] The formation approach of the thin film which deposits iron and is characterized by forming the beta iron silicide layer of n mold or p mold by the reaction with the silicon of said silicon substrate while heating said silicon substrate after carrying out the ion implantation of the doping impurity used as n mold or p mold to a silicon substrate surface.
[Claim 13] The formation approach of the thin film according to claim 12 characterized by carrying out the ion implantation of manganese, chromium, or molybdenum as a doping impurity used as n mold as a doping impurity which serves as p mold in cobalt, nickel, platinum, or palladium.
[Claim 14] The formation approach of a thin film given in either of claims 9, 10, or 12 to which the dose of an ion implantation is characterized by being the range of 5x1012cm-2 to 1x1015cm-2.
[Claim 15] The formation approach of the thin film according to claim 9, 10, or 12 characterized by being the

range of less than 3.2 times of the thickness of the iron which the range of the depth direction of an ion implantation deposits from a silicon substrate surface.
[Claim 16] The formation approach of the thin film according to claim 9, 10, or 12 characterized by depositing iron in the state of an anion.
[Claim 17] The formation approach of the thin film according to claim 9, 10, or 12 characterized by depositing iron using the spatter which used krypton gas or xenon gas.
[Claim 18] The formation approach of the thin film characterized by piling up and heat-treating the 2nd silicon substrate to the front-face side of said 1st silicon substrate, and embedding and forming a beta iron silicide layer between said 1st silicon substrate and said 2nd silicon substrate after depositing iron on the front face of the 1st silicon substrate and forming an iron deposit.
[Claim 19] The formation approach of the thin film according to claim 18 characterized by carrying out hydrophilic processing and piling up one [at least] silicon substrate of the 1st silicon substrate and the 2nd silicon substrate.
[Claim 20] The formation approach of the thin film according to claim 18 characterized by heat-treating the 1st silicon substrate on which you made it put each other, and the 2nd silicon substrate in the ambient atmosphere containing hydrogen gas, nitrogen gas, or argon gas.
[Claim 21] The formation approach of the thin film according to claim 18 characterized by carrying out the ion implantation of iron or the silicon beforehand at least before [the 1st silicon substrate and the 2nd silicon substrate] depositing iron on one of substrate front faces.
[Claim 22] The formation approach of the thin film according to claim 18 characterized by carrying out the ion implantation of the rare gas of neon, an argon, a krypton, or a xenon beforehand at least before [the 1st silicon substrate and the 2nd silicon substrate] depositing iron on one of substrate front faces.
[Claim 23] The formation approach of the thin film according to claim 18 characterized by carrying out the ion implantation of the doping impurity which serves as n mold or p mold beforehand at least before [the 1st silicon substrate and the 2nd silicon substrate] depositing iron on one of substrate front faces.
[Claim 24] The formation approach of the thin film according to claim 23 characterized by carrying out the ion implantation of manganese, chromium, or molybdenum as a doping impurity used as n mold as a doping impurity which serves as p mold in cobalt, nickel, platinum, or palladium.
[Claim 25] The formation approach of a thin film according to claim 21 to 24 that the dose of an ion implantation is characterized by being the range of 5x1012cm-2 to 1x1015cm-2.

[Translation done.]

* NOTICES *

JPO and NCIPI are not responsible for any damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the formation approach of the thin film which forms beta iron silicide (it is hereafter described as beta-FeSi 2) on a silicon (it is hereafter described as Si) substrate.
[0002]
[Description of the Prior Art] There are very many classes of the silicide which is the compound of Si and a metal, and research has so far been done mainly as an electrode material. Recently, beta-FeSi 2 attracts attention as silicide with the property of a semi-conductor. Beta-FeSi 2 can have the band gap (- 0.85eV) of a direct transition mold, can grow epitaxially on Si substrate, and it inquires also as an ingredient of a thermoelement in ancient times, and it is expected as a solar battery or a leading ingredient of luminescence device implementation of Si in recent years.
[0003] Many things are reported until now as the formation approach of a up to [beta-FeSi two-layer Si substrate]. There are following three as the typical membrane formation approach.
[0004] The 1st is the approach (Solid Phase Epitaxy law; the SPE method) of forming according to the solid phase reaction of Fe and Si by annealing in the state of a room temperature after depositing iron (it being hereafter described as Fe) on Si substrate. This is for example, J.Derrien. et It is indicated by al., Appl.Surf.Sci., and 73 (1993) 90.
[0005] The 2nd is the approach (Reactive Deposition Epitaxy law; the RDE method) of forming according to the solid phase reaction of Fe and Si, depositing Fe on heated Si substrate. This is for example, A.H.Reader. et It is indicated by al., Appl.Surf.Sci., and 73 (1993) 131.
[0006] It is the approach (the Molecular Beam Epitaxy method; it is the MBE method.) of forming, while the 3rd deposits Fe and Si on coincidence on Si substrate heated in the MBE chamber. This is for example, J.E.Mahan. et It is indicated by al., Appl.Phys.Lett., and 56 (1900) 2126.
[0007] In order to deposit Fe by the SPE method and the RDE method, electron beam (EB) vacuum evaporationo and the spatter using Ar gas are usually used.
[0008]
[Problem(s) to be Solved by the Invention] In the SPE method and the RDE method which deposit Fe on Si substrate, in order to form the epitaxial layer of beta-FeSi 2, it is required for a reaction to arise at a rate of two Si atoms to one Fe atom, and beta-FeSi two-layer about 3.2 times the thickness of deposited Fe layer is formed.
[0009] Beta-FeSi 2 has the crystal structure of a prismatic crystal, and as shown in Table 1 to Si substrate, the epitaxial layer of beta-FeSi 2 is obtained by the relation between the crystal face and a crystallographic axis.
[0010]
[Table 1]

基板	結晶面	結晶軸
Si(100)	β-FeSi2(100)//Si(100)	β-FeSi2[010]、又はβ-FeSi2[001]//Si[110]
Si(111)	β-FeSi2(101)//Si(111)	β-FeSi2[010] //Si[011]
Si(111)	β-FeSi2(110)//Si(111)	β-FeSi2[001] //Si[011]

[0011] However, in order to promote this reaction, if the thickness of Fe layer which hot heat treatment is required, and the above-mentioned crystal relation is not uniquely determined by the primary reaction as compared with the RDE method, and is deposited first is thick, unreacted Fe will remain and it will be easy to

become polycrystal by the SPE method.
[0012] On the other hand, by the RDE method, since Fe is deposited on Si substrate heated from the beginning, as compared with the SPE method, it is easy to produce the above-mentioned crystal relation, but if the rate of sedimentation (DEPORETO) of Fe becomes quick especially, Si atom which reacts will run short from the relation of Fe:Si=1:2, beta-FeSi two-layer formation will become difficult, and membrane formation conditions will be limited.
[0013] Moreover, if the epitaxial layer thickness of beta-FeSi 2 formed becomes thick exceeding 50nm, diffusion of Si atom becomes slow, a reaction with Fe atom will be controlled and the SPE method and the RDE method will tend to become polycrystal.
[0014] Next, by the MBE method, it is hard to opt for the first crystalline-nucleus formation uniquely like the SPE method. Then, the template method which carries out the vacuum evaporationo deposition only of the Fe ultra-thin with about 1nm like the RDE method at first, and forms the epitaxial layer of thin beta-FeSi 2, and a mole ratio 1:2 comes out of Fe and Si comparatively, and carries out simultaneous vacuum evaporationo by making it into a template is used well. However, by this approach, there is a fault to which a process becomes complicated too much.
[0015] Moreover, since beta-FeSi's 2 having the crystal structure of a prismatic crystal and low-temperature formation of Si are required, it is very difficult to form Si epitaxial layer further on the epitaxial layer of beta-FeSi 2 formed on Si substrate, and to acquire double hetero structure.
[0016] Moreover, the doping technique used as beta-FeSi two-layer n mold or p mold by the impurity also has difficulty in a controllability, although the coincidence vacuum evaporationo by the electron beam evaporation and the spatter of an impurity atom and Fe atom is generally used.
[0017] This invention was made in order to solve such a technical problem, and it offers the membrane formation approach which enables formation of the highly precise doping technique to the quality epitaxial layer of beta-FeSi 2, and the epitaxial layer of beta-FeSi 2, and the double hetero structure epitaxial layer of 2/Si of Si/beta-FeSi on Si substrate.
[0018]
[Means for Solving the Problem] In order to solve the above-mentioned technical problem, deposit Fe on deposition, and the formation approach of claim 1 of this invention and a thin film given in two makes coincidence, or Fe and Si deposit Fe and Si by turns on heated Si substrate using the spatter which used krypton (it is hereafter described as Kr) gas, or xenon (it is hereafter described as Xe) gas, and forms beta-FeSi two-layer on Si substrate.
[0019] Thereby, since Si substrate is exposed to these plasma gas as compared with the argon (it is hereafter described as Ar) gas usually used by the spatter at the time of Fe deposition mass is large and according to a spatter, the reaction of Fe and Si of Si substrate which dissociation of Si-Si association of Si substrate front face progresses efficiently, and are deposited is promoted, and Kr gas and Xe gas can form the epitaxial layer of quality beta-FeSi 2.
[0020] Moreover, the formation approach of the thin film of this invention according to claim 3 makes Fe deposit in the state of an anion on heated Si substrate, and forms beta-FeSi two-layer on Si substrate by the reaction with Si of Si substrate.
[0021] Thereby, accompanying energy of an anion is smaller than the electrolytic dissociation energy of the cation usual by the electron affinity, since it carries the kinetic energy to the ligation reaction of Fe and Si efficiently, the reaction is promoted and it can form the epitaxial growth of quality beta-FeSi 2.
[0022] Moreover, the formation approach of claims 4 and 5 of this invention, and a thin film given in six In the process which deposits Fe on heated Si substrate, or deposits Fe and Si on coincidence, and forms beta-FeSi two-layer on Si substrate Si substrate top -- hydrogen (it is hereafter described as H), or rare gas -- {-- concrete -- the radical ion of}, such as neon (it is hereafter described as Ne), and Ar, Kr, Xe, -- deposition of deposition and coincidence of Fe, or Fe and Si -- simultaneously -- or the process irradiated by turns is included.
[0023] Thereby, by exposing Si substrate to the radical ion of rare gas, such as H, or Ne, Ar, Kr, Xe, by dissociation of Si-Si association of Si substrate front face progressing efficiently, and giving the ion energy, the ligation reaction of Fe and Si to deposit is promoted and the epitaxial layer of quality beta-FeSi 2 can be formed.
[0024] Moreover, this invention according to claim 7 deposits iron in the state of an anion in the formation

approach according to claim 4 or 5.
[0025] Thereby, accompanying energy of an anion is smaller than the electrolytic dissociation energy of the cation usual by the electron affinity, and the reaction is promoted in order to carry the kinetic energy to the ligation reaction of Fe and Si efficiently.
[0026] Moreover, this invention according to claim 8 heats a silicon substrate in 400-700 degrees C in the formation approach according to claim 1 to 5.
[0027] Thereby, crystallization advances the optimal.
[0028] Moreover, after the formation approach of claims 9 and 10 of this invention and a thin film given in 11 carries out the ion implantation of Fe, Si, or the rare gas (specifically Ne, Ar, Kr, Xe, etc.) to Si substrate front face, heating Si substrate, it deposits Fe and forms beta-FeSi two-layer by the reaction with Si of Si substrate.
[0029] Thereby, by carrying out the ion implantation of the rare gas, such as Fe, Si, or Ne, Ar, Kr, Xe, to Si substrate beforehand, these impregnation atoms collide with Si atom of Si substrate, lose the energy, and stop at the location between grids. Therefore, Si-Si association of Si substrate front face dissociates, the reaction of Fe and Si of Si substrate which are deposited after that is promoted, and the EPIKYASHITARU layer of quality beta-FeSi 2 can be formed.
[0030] Moreover, the formation approach of a thin film claim 12 and given in 13 deposits Fe, heating Si substrate for the doping impurity (specifically manganese, chromium, molybdenum) used as the doping impurity (specifically cobalt, nickel, platinum, palladium) or p mold used as n mold after an ion implantation on Si substrate front face, and forms the beta-FeSi two-layer of n mold or p mold by the reaction with Si of Si substrate.
[0031] By this, an impurity can be taken in by the beta-FeSi two-layer formed while the reaction of Fe and Si of Si substrate which the impurity poured in like said invention according to claim 9 to 11 makes dissociate Si-Si association of the front face of Si substrate, and are deposited on Si substrate after that is promoted, and it can permute by Fe, and can dope with a sufficient controllability in n mold or p mold.
[0032] Moreover, in the formation approach given in above-mentioned claims 9, 10, or 12, the range of the dose of an ion implantation of invention according to claim 14 is 5x1012cm-2 to 1x1015cm-2.
[0033] Thereby, the damage by the ion implantation can be reduced.
[0034] Moreover, invention according to claim 15 is made into the range of less than about 3.2 times of the thickness of Fe which the range of the depth direction of an ion implantation deposits from Si substrate front face in the formation approach according to claim 9, 10, or 12.
[0035] Thereby, since the range of the depth direction by which an ion implantation is carried out is the field in which the epitaxial layer of beta-FeSi 2 is formed, the epitaxial layer of still more nearly quality beta-FeSi 2 can be formed.
[0036] Moreover, invention according to claim 16 makes iron deposit in the state of an anion in the formation approach according to claim 9, 10, or 12.
[0037] Thereby, accompanying energy of an anion is smaller than the electrolytic dissociation energy of the cation usual by the electron affinity, and the reaction is promoted in order to carry the kinetic energy to the ligation reaction of Fe and Si efficiently.
[0038] Moreover, invention according to claim 17 makes Fe deposit in the formation approach according to claim 9, 10, or 12 using the spatter which used Kr gas or Xe gas.
[0039] Thereby, the reaction of Si of Fe and Si substrate which dissociation of Si-Si association of Si substrate front face progresses efficiently, and is deposited is promoted.
[0040] Moreover, after the formation approach of the thin film of this invention according to claim 18 deposits Fe on the front face of 1st Si substrate, it piles up and heat-treats 2nd Si substrate to the front-face side of 1st Si substrate, and embeds and forms beta-FeSi two-layer between both Si substrates.
[0041] Fe produces Si substrate and solid phase reaction of both sides, and it is the form where the epitaxial layer of beta-FeSi 2 is embedded in Si layer of both sides, and bonding of the two Si substrates is carried out, and it can form easily the double hetero structure of Si/beta-FeSi 2 / Si because this heat-treats in piles 1st Si substrate which deposited Fe with 2nd Si substrate.
[0042] Moreover, in the formation approach according to claim 18, hydrophilic processing is carried out and invention according to claim 19 piles up one [at least] silicon substrate of the 1st silicon substrate and the 2nd silicon substrate.

[0043] Thereby, the adhesion of 1st and 2nd Si substrate becomes good.
[0044] Moreover, invention according to claim 20 heat-treats the 1st piled-up silicon substrate and the 2nd silicon substrate in the formation approach according to claim 18 in the ambient atmosphere containing hydrogen gas, nitrogen gas, or argon gas.
[0045] Thereby, without Fe reacting to a controlled atmosphere, it is spread in both Si substrates and solid phase reaction is promoted.
[0046] Moreover, in the formation approach according to claim 18, at least, invention of a publication carries out the ion implantation of the rare gas of Fe, Si, or Ne, Ar, Kr or Xe to claims 21 and 22 beforehand, before [the 1st silicon substrate and the 2nd silicon substrate] depositing iron on one of substrate front faces.
[0047] Thereby, the ligation reaction of Fe and Si of Si substrate to deposit is promoted by exposing Si substrate to these ion by dissociation of Si-Si association of Si substrate front face progressing efficiently, and giving the ion energy.
[0048] Moreover, in the formation approach according to claim 18, at least, invention given in claims 23 and 24 carries out the ion implantation of the doping impurity (specifically manganese, chromium, molybdenum) used as the doping impurity (specifically cobalt, nickel, platinum, palladium) or p mold which turns into n mold beforehand, before depositing iron on the 1st silicon substrate surface.
[0049] Thereby, the poured-in impurity can be taken in by the beta-FeSi two-layer formed of the reaction of Fe and Si of Si substrate which are deposited on Si substrate, can be permuted by Fe, and can be doped with a sufficient controllability in n mold or p mold.
[0050] Moreover, in the formation approach according to claim 21 to 24, the range of the dose of an ion implantation of invention according to claim 25 is 5x1012cm-2 to 1x1015cm-2.
[0051] Thereby, the damage by which an ion implantation is carried out can be reduced.
[0052]
[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained with reference to a drawing.
[0053] (Gestalt 1 of operation) Drawing 1 is the schematic diagram of equipment and the sectional view of a substrate showing the formation approach of the thin film in the 1st operation gestalt of this invention.
[0054] First, as shown in drawing 1 (a), after washing {it is hereafter described as RCA (Radio Corporation of America) washing} which uses ammonia hydrogen peroxide solution and hydrochloric-acid hydrogen peroxide solution for the Si substrate 1 of n mold of a field (100) by turns, hydrogen termination processing is performed by rare fluoric acid, and it installs in the substrate electrode holder 3 arranged in the vacuum chamber 2 of magnetron sputtering equipment.
[0055] In addition, the exhaust port 5 connected with the heater 4 for heating the Si substrate 1 at the pump for carrying out evacuation and cathodes 6 and 7 are formed in the vacuum chamber 2, and the Si target 9 is formed on the Fe target 8 and the cathode 7 on the cathode 6, respectively. Moreover, in order to supply power to cathodes 6 and 7, the 13.56MHz RF power sources 10 and 11 are established through matching boxes 12 and 13, respectively. Furthermore, the gas supply opening 14 for supplying sputtering gas to the vacuum chamber 2 is formed, and the Xe gas 16 by which control of flow was carried out with the massflow controller 15 is sent in in the vacuum chamber 2 from gas supply opening.
[0056] The above-mentioned equipment is used. Substrate temperature at a heater 4 Next, 550-650 degrees C, A spatter pressure with a massflow controller 15 and exhaust air 5mmTorr(s), As Xe flow rate is set as 25SCCM (s) and shown in drawing 1 (b) using 200W and a massflow controller 15, RF power of the RF power source 10 impressed to Fe target if 30nm n thickness is made to deposit Fe in about 3nm DEPORETO for /on the Si substrate 1 of n mold -- substrate heating -- Si and Fe of the Si substrate 1 -- reacting -- the Si substrate 1 top -- beta-FeSi two-layer -- 17 can be formed in the thickness of about 100nm.
[0057] the beta-FeSi two-layer formed by the approach by which Xe gas of this invention was used for drawing 2 in this way -- the result of the beta-FeSi two-layer X diffraction formed by the approach using conventional Ar gas is indicated to be 17.
[0058] In addition, in the case of Ar gas, DEPORETO of Fe was adjusted so that it might become almost the same as the case of Xe gas.
[0059] Although, as for the sample by the formation approach of this invention using Xe gas, it turns out that the peak of (400) of beta-FeSi 2, (600), and the single crystal phase of a field (800) is seen, and the quality

epitaxial film is formed as shown in drawing 2 , it turns out that the peak of the sample (202) by the conventional formation approach using Ar gas or a field (422) was seen, and single crystal nature has deteriorated.
[0060] Moreover, by the approach using conventional Ar gas, when beta-FeSi two-layer thickness exceeded 50-100nm, it became polycrystal, but by the approach using Xe gas of this invention, even if beta-FeSi two-layer thickness exceeded 200nm, single crystal nature was maintained.
[0061] (Gestalt 2 of operation) with the 1st operation gestalt, although only Fe was deposited in the spatter, it is shown in drawing 3 -- as -- the formation approach of the thin film of the 2nd operation gestalt of this invention -- both Fe and Si -- a spatter -- the Si substrate 1 of n mold of a field (100) -- coincidence -- depositing -- beta-FeSi two-layer -- 17 is formed. Since it is the same as that of what was shown in drawing 1 (a), the equipment used for the formation approach of the thin film of the gestalt the 2nd operation and arrangement of Si substrate are explained with reference to drawing 1 (a).
[0062] The equipment of drawing 1 is used. 550-650 degrees C and a spatter pressure for substrate temperature 5mmTorr(s), RF power of 200W and the Si target 9 for RF power of the Fe target 8 150W, Xe flow rate is set as 25SCCM(s), Fe and Si are made to deposit on the Si substrate 1 in about 3nm a part for /and DEPORETO for about 10nm/, respectively, as shown in drawing 3 , and beta-FeSi two-layer 17 is formed on the Si substrate 1 at the thickness of about 100nm. The X diffraction which shows the same quality epitaxial layer as what was shown in drawing 2 also in this case was acquired.
[0063] Why a quality EPIKYASHITARU layer is formed as the gestalt of the 1st and the 2nd operation showed Xe gas has big mass as compared with Ar, and faces the collision with Si atom. The contribution of the energy to Si atom is small as compared with Ar, and the probability to collide with many Si atoms since the atomic radius is large is large. It is because energy is given to many Si atoms of a growth surface layer by the low damage, so the reaction of Fe and Si of Si substrate which dissociation of Si-Si association of Si substrate front face progresses efficiently, and are deposited is promoted. Moreover, although there is few extent, it is because the same situation is realized also about the collision with Fe atom.
[0064] Above, although coincidence deposition of Fe and Si was explained, the same effectiveness is acquired even if it deposits Fe and Si by turns.
[0065] Moreover, in explanation of the 1st and 2nd operation gestalten, although Xe gas was explained, there is effectiveness with the same said of Kr gas. Moreover, although Si substrate of n mold of a field (100) was described, there is effectiveness with the same said of Si substrate of p mold of a field (100) and Si substrate of n mold of a field (111) or p mold. Moreover, although the RF magnetron sputtering method was explained, the result same about other spatters, such as DC spatter and 2 pole spatter, is obtained.
[0066] (Gestalt 3 of operation) Drawing 4 is the schematic diagram of equipment and the sectional view of a substrate showing the formation approach of the thin film by the 3rd operation gestalt of this invention.
[0067] As shown in drawing 4 (a), first, hydrogen termination processing is performed by rare fluoric acid after RCA washing, and the Si substrate 1 of n mold of a field (100) is installed in the substrate electrode holder 19 arranged in the vacuum chamber 18 of ion beam vacuum evaporationo equipment. In addition, RF plasma spatter type negative heavy ion source 22 for generating the exhaust port 21 connected to the heater 20 for heating the Si substrate 1 and the pump for carrying out evacuation and the anion of Fe is formed in the vacuum chamber 18. Moreover, the RF power source 23 and the matching box 24 are connected to RF plasma spatter type negative heavy ion source 22.
[0068] Drawing 5 shows structural drawing of RF plasma spatter type negative heavy ion source 22. This RF plasma spatter type negative heavy ion source 22 makes the anion of Fe form by striking the Fe target 26 with which Cs adhered to the front face by plasma discharge of Xe gas 27 by supplying the neutral caesium (it being hereafter described as Cs) steam 25. Moreover, the energy of ion can be adjusted with the drawer electrode 28. In addition, 29 is a high frequency coil and 30 is a magnet.
[0069] Next, using the above-mentioned equipment, supply the Xe gas 27 of the low voltage force of a 10-4Torr base to RF plasma spatter type negative heavy ion source 22, and about 300W of 13.56MHz RF power is impressed. Generate the anion of Fe, the anion of Fe is made to irradiate the Si substrate 1 heated at 550-650 degrees C by about 3nm DEPORETO for /, as shown in drawing 4 (b), and beta-FeSi two-layer 17 is formed on the Si substrate 1 at the thickness of about 100nm. The X diffraction which shows the same quality epitaxial layer as what was shown in drawing 2 also in this case was acquired.

[0070] Accompanying energy is an electron affinity (usually - about 1eV), and an anion is smaller than the electrolytic dissociation energy (usually - 10eV) of the usual cation, and it is because the reaction is promoted and the epitaxial growth of quality beta-FeSi 2 becomes possible, since this carries the kinetic energy to the ligation reaction of Fe and Si efficiently. In this case, as energy of the anion of Fe, about (2-8eV) several eV is desirable. If the energy of the anion of Fe becomes not much high exceeding 10eV, a damage will occur and membraneous quality will deteriorate.
[0071] (Gestalt 4 of operation) Drawing 6 is the schematic diagram of equipment and the sectional view of a substrate showing the formation approach of the thin film by the 4th operation gestalt of this invention.
[0072] As shown in drawing 6 (a), hydrogen termination processing by rare fluoric acid is performed after RCA washing, and the Si substrate 1 of n mold of a field (100) is installed in the substrate electrode holder 32 arranged in the vacuum chamber 31 of high vacuum electron-beam-evaporation equipment.
[0073] In addition, the exhaust port 34 connected to the heater 33 for heating the Si substrate 1 and the pump for carrying out evacuation, the E gun 35 of Fe for the electron beam evaporation of Fe, the E gun 36 of Si for the electron beam evaporation of Si, and the source 37 of RF radical ion for the gas sources are established in the vacuum chamber 31. In addition, as for RF power source and 39, 38 is [a matching box and 40] a massflow controller and 41H2 gas.
[0074] Next, using the above-mentioned equipment, set substrate temperature as 550-650 degrees C, and carry out 2SCCM supply of theHsource of RF radical ion 2 gas 41, and RF power of 150W is impressed [37] from the RF power source 38. Fe is deposited on 30nm thickness in about 1nm DEPORETO for /with an electron beam, irradiating the radical ion 42 of H at the Si substrate 1, as shown in drawing 6 (b) -- making -- the Si substrate 1 top -- beta-FeSi two-layer -- 17 is formed in the thickness of about 100nm. The X diffraction which shows the same quality epitaxial layer as what was shown in drawing 2 also in this case was acquired.
[0075] If the H radical ion 42 is irradiated by the Si substrate 1, in order that this may react with Si atom and may form SiH4, it is because the ligation reaction of Fe and Si to deposit is promoted by dissociation of Si-Si association of the front face of the Si substrate 1 progressing efficiently, and giving the ion energy. By this, the epitaxial layer of quality beta-FeSi 2 can be formed. In addition, in the above-mentioned explanation, although the exposure of the radical ion of H and deposition of Fe were performed to coincidence, you may carry out by turns.
[0076] (Gestalt 5 of operation) With the 4th operation gestalt of this invention, although only Fe was deposited in electron beam evaporation, in the 5th operation gestalt of this invention, the case where deposit Fe and Si on coincidence and beta-FeSi two-layer is formed is explained. Since it is the same as that of what was shown in drawing 6 (a), equipment and arrangement of Si substrate are explained with reference to drawing 6 (a).
[0077] The substrate temperature of the Si substrate 1 of n mold of a field (100) is set as 550-650 degrees C using the equipment shown in drawing 6 (a). Carry out 2SCCM supply of theHsource of RF radical ion 2 gas 41, and RF power of 150W is impressed [37] according to the RF power source 38. Fe and Si are deposited on coincidence with an electron beam in about 1nm a part for /and DEPORETO for about 3.3nm/, respectively, irradiating the radical ion 42 of H at the Si substrate 1, as shown in drawing 7 -- making -- the Si substrate 1 top -- beta-FeSi two-layer -- 17 is formed in the thickness of about 100nm. The X diffraction which shows the same quality epitaxial layer as what was shown in drawing 2 also in this case was acquired.
[0078] In the above-mentioned explanation, although coincidence deposition of Fe and Si was explained, even if it deposits Fe and Si by turns, the same effectiveness is acquired. Moreover, although the exposure of the radical ion of H and deposition of Fe and Si were performed to coincidence, you may carry out by turns.
[0079] Although explanation of the 4th and 5th operation gestalten explained the case where 37Hsource of RF radical ion 2 gas was used, also when rare gas, such as Xe and Kr, is used, by dissociation of Si-Si association of Si substrate front face progressing efficiently, and giving the ion energy, the ligation reaction of Fe and Si to deposit is promoted and the same effectiveness is acquired.
[0080] Moreover, although electron beam evaporation of the Fe was carried out, if it deposits in the state of an anion as shown in the gestalt 3 of operation, the beta-FeSi two-layer of high quality will be obtained further.
[0081] Moreover, although Si substrate of n mold of a field (100) was described, the same is said of Si substrate of p mold of a field (100), and Si substrate of n mold of a field (111), or p mold.
[0082] Moreover, although 550-650 degrees C was used as substrate temperature with the gestalt 5 of operation from the gestalt 1 of operation, if it is the range of 400-750 degrees C, quality beta-FeSi two-layer membrane

formation can be performed.
[0083] (Gestalt 6 of operation) Drawing 8 is the process sectional view of the substrate in which the formation approach of the thin film by the 6th operation gestalt of this invention is shown.
[0084] First, as shown in drawing 8 (a), after RCA washing and using an ion-implantation machine, acceleration voltage injects by 100keV(s), a dose injects Fe56 ion into the front face of the Si substrate 1 for the Si substrate 1 of n mold of a field (100) on condition that 3x1014cm-2, and Fe impregnation layer 43 is formed.
[0085] As shown in drawing 8 (b), again the Si substrate 1 with which Fe was poured in Next, after RCA washing, Perform hydrogen termination processing by rare fluoric acid, and the usual magnetron sputtering equipment using Ar gas is used after that. The same conditions, i.e., substrate temperature, as the gestalt of the 1st operation showed 550-650 degrees C, RF power of 5mmTorr(s) and Fe target is set as 200W, Ar flow rate is set as 25SCCM(s) for a spatter pressure, and Fe is deposited in about 3nm DEPORETO for /on the Si substrate 1 at the thickness of 30nm -- making -- beta-FeSi two-layer -- 17 is formed in the thickness of about 100nm. The X diffraction which shows the same quality epitaxial layer as what was shown in drawing 2 also in this case was acquired.
[0086] Fe atom poured in when this carried out the ion implantation of the Fe to Si substrate beforehand is for Fe which it collided with Si atom of Si substrate, the energy was lost, it stopped at the location between grids, and the reaction of Fe and Si which Si-Si association of Si substrate front face dissociates by this, and are deposited on heated Si substrate was promoted, and was poured in also contributing to a reaction with Si. By this, the epitaxial layer of quality beta-FeSi 2 can be formed.
[0087] Although the above-mentioned explanation explained the case where the ion implantation of the Fe was carried out, the same effectiveness is acquired even if it carries out the ion implantation of the Si which is the configuration element of the same beta-FeSi 2.
[0088] (Gestalt 7 of operation) Drawing 9 is the process sectional view of the substrate in which the formation approach of the thin film by the 7th operation gestalt of this invention is shown.
[0089] First, as shown in drawing 9 (a), after RCA washing and using an ion-implantation machine, acceleration voltage injects by 45keV(s), a dose injects Ar40 ion into the front face of the Si substrate 1 for the Si substrate 1 of n mold of a field (100) on condition that 1x1014cm-2, and Ar impregnation layer 44 is formed.

[0090] As shown in drawing 9 (b), again the Si substrate 1 with which Ar was poured in Next, after RCA washing, After performing hydrogen termination processing by rare fluoric acid, the usual magnetron sputtering equipment using Ar gas is used. The same conditions, i.e., substrate temperature, as the gestalt of the 1st operation showed 550-650 degrees C, RF power of 5mmTorr(s) and Fe target is set as 200W, Ar flow rate is set as 25SCCM(s) for a spatter pressure, on the Si substrate 1, the thickness of 30nm is made to deposit Fe in about 3nm DEPORETO for /, and beta-FeSi two-layer 17 is formed at about 100nm thickness. The X diffraction which shows the same quality epitaxial layer as what was shown in drawing 2 also in this case was acquired.
[0091] It is because the reaction of Fe and Si which Ar atom poured in when this carried out the ion implantation of the Ar to Si substrate beforehand collides with Si atom of Si substrate, loses the energy, and stops at the location between grids, and Si-Si association of Si substrate front face dissociates by this, and are deposited on heated Si substrate is promoted. By this, the epitaxial layer of quality beta-FeSi 2 can be formed.
[0092] Although poured-in Ar atom remains in Si substrate at this time, since it is a neutral impurity, it does not have effect of what, either.
[0093] Although the above-mentioned explanation explained the case where Ar was poured in, the same effectiveness is acquired even if it pours in Ne, Kr, and Xe of the same rare-gas atom.
[0094] Moreover, it sets in the gestalt 6 of operation, and the gestalt 7 of operation. If there are many doses of impregnation of Fe ion or Ar ion, in order that a damage may remain into Si substrate, The range of a dose of 5x1012cm-2 to 1x1015cm-2 is desirable, and, as for the range of the depth of an ion implantation, it is desirable to be limited to the field (less than about 3.2 times of the thickness of Fe deposited from Si substrate front face) in which the epitaxial layer of beta-FeSi 2 is formed.
[0095] (Gestalt 8 of operation) Drawing 10 is the process sectional view of the substrate in which the formation approach of the thin film by the 8th operation gestalt of this invention is shown.
[0096] First, as shown in drawing 10 (a), after RCA washing and using an ion-implantation machine, acceleration voltage injects by 100keV(s), a dose injects cobalt (it is hereafter described as Co) ion into the front

face of the Si substrate 1 for the Si substrate 1 of n mold of a field (100) on condition that 3x1014cm-2, and Co impregnation layer 45 is formed.
[0097] As shown in drawing 10 (b), again the Si substrate 1 with which Co was poured in Next, after RCA washing, Perform hydrogen termination processing by rare fluoric acid, and the usual magnetron sputtering equipment using Ar gas is used. The same conditions, i.e., substrate temperature, as the gestalt of the 1st operation showed 550-650 degrees C, RF power of 5mmTorr(s) and Fe target for a spatter pressure 200W, the beta-FeSi two-layer of n mold which set Ar flow rate as 25SCCM(s), and the thickness of 30nm was made to deposit Fe in about 3nm DEPORETO for /on the Si substrate 1, and doped Co -- 46 is formed in the thickness of about 100nm. The X diffraction which shows the same quality epitaxial layer as what was shown in drawing 2 also in this case was acquired.
[0098] This by carrying out the ion implantation of the Co of the impurity which serves as n mold beforehand to Si substrate Poured-in Co atom collides with Si atom of Si substrate, loses the energy, and stops at the location between grids. By this It is because Co into which the reaction of Fe and Si which Si-Si association of Si substrate front face dissociates, and are deposited on heated Si substrate was promoted and poured permutes by Fe. By this, the epitaxial layer of beta-FeSi 2 of quality n mold of Co dope can be formed.
[0099] In addition, although beta-FeSi two-layer is usually p mold, the beta-FeSi two-layer of n mold is obtained by doping Co.
[0100] Moreover, the amount of doping can be changed with a sufficient controllability with the dose of an ion implantation.
[0101] Although the above-mentioned explanation explained the case where the ion implantation of the Co was carried out, even if it uses manganese (Mn), chromium (Cr), molybdenum (Mo), etc. as nickel (nickel), platinum (Pt), palladium (Pd), and an impurity of p mold, the same effectiveness is acquired as an impurity of n mold.
[0102] Moreover, if there are many doses of an ion implantation, in order that a damage may remain into Si substrate like the gestalt 6 of operation, and the gestalt 7 of operation, the range of a dose of 5x1012cm-2 to 1x1015cm-2 is desirable, and, as for the range of the depth direction of an ion implantation, it is desirable to be limited to the field (less than about 3.2 times of the thickness of Fe deposited from Si substrate front face) in which the epitaxial layer of beta-FeSi 2 is formed.
[0103] Moreover, although explanation of the 6th, 7th, and 8th operation gestalten explained how to deposit Fe using the usual magnetron sputtering method for having used Ar gas Other spatter approaches, such as DC spatter, 2 pole spatter, and an ion beam spatter, The same effectiveness mentioned above also by the spatter approach using the electron-beam-evaporation approach, Xe gas shown with the gestalt of the 1st operation, and Kr gas and the approach of depositing Fe shown with the gestalt of the 3rd operation in the state of an anion is acquired.
[0104] Moreover, although Si substrate of n mold of a field (100) was described, effectiveness with the same said of Si substrate of p mold of a field (100) and Si substrate of n mold of a field (111) or p mold is acquired.
[0105] (Gestalt 9 of operation) Drawing 11 is the process sectional view of the substrate in which the formation approach of the thin film by the 9th operation gestalt of this invention is shown.
[0106] As shown in drawing 11 (a), first, the Si substrate 1 of n mold of a field (100) Perform hydrogen termination processing by rare fluoric acid after RCA washing, and the usual magnetron sputtering equipment using Ar gas is used. RF power of 5mmTorr(s) and Fe target is set as 200W, Ar flow rate is set [substrate temperature] as 25SCCM(s) for ordinary temperature and a spatter pressure, on the Si substrate 1, the thickness of 60nm is made to deposit Fe in about 3nm DEPORETO for /, and the Fe layer 47 is formed. In addition, 250 degrees C or less which the reaction of Fe and Si does not produce are suitable for substrate temperature.
[0107] Next, as shown in drawing 11 (b), after making the Si substrate 48 of p mold of a field (100) permeate H2O2-H2SO4 solution etc. and performing hydrophilic processing, it is made to rival in piles and is made to stick so that the Fe layer 47 on the Si substrate 1 of n mold may be pinched in between.
[0108] Next, as shown in drawing 11 (c), it heat-treats in a 1 hour H2 gas ambient atmosphere with the temperature of 700 degrees C using an electric furnace. By this heat treatment, it is spread in both Si substrates, without Fe atom reacting to a controlled atmosphere, solid phase reaction arises, it is formed in the form where the epitaxial layer 17 of beta-FeSi 2 is embedded in Si layer of both sides, and bonding of the two substrates is carried out.

[0109] Then, as shown in drawing 11 (d), the Si substrate 48 of p mold is ground, and it is made desired thickness. Thereby, the double hetero structure of p-Si/beta-FeSi 2 / n-Si which can form a semiconductor device can be formed.
[0110] Although the above-mentioned explanation explained the case where H2 gas ambient atmosphere was used by heat treatment, the same effectiveness is acquired even if it uses nitrogen (N2) gas and Ar gas. Moreover, about hydrophilic processing of Si substrate, the Si substrate 1 of n mold may be used, and it should carry out about either at least.
[0111] Moreover, although how to deposit Fe using the usual magnetron sputtering method using Ar gas was explained, the same effectiveness is acquired even if it uses the spatter using other spatter approaches, such as DC spatter, 2 pole spatter, and an ion beam spatter, electron beam vacuum deposition, Xe gas shown with the gestalt of the 1st operation, and Kr gas.
[0112] As the gestalt of the 8th operation showed from the 6th, moreover, to the Si substrate 1 of n mold of a field (100), or (100) the Si substrate 48 of p mold of a field There is same effectiveness mentioned above even if it carried out the ion implantation of Co, nickel and Pd which serve as rare gas, such as Fe, Si, or Ne, Ar, Kr, Xe, or n mold impurity beforehand, Mn, Cr, Mo used as p mold impurity, etc. before depositing Fe.
[0113]
[Effect of the Invention] By using the spatter which used Kr gas or Xe gas although this invention deposits Fe on heated Si substrate By changing into the condition of an anion and depositing Fe, moreover, moreover, by depositing Fe, irradiating the radical ion of rare gas, such as H, Ne, Ar, Kr, and Xe, on Si substrate Moreover, by depositing Fe, since the ion implantation of the rare gas, such as Fe, Si, or Ne, Ar, Kr, Xe, is beforehand carried out to Si substrate The reaction of Fe and Si which dissociation of Si-Si association of Si substrate front face progresses efficiently, and are deposited is promoted, and the formation approach of a thin film of having the outstanding effectiveness that the epitaxial layer of beta-FeSi 2 of high quality is formed can be offered.
[0114] Moreover, by heating Si substrate which carried out the ion implantation of Co, nickel, Pt and Pd used as the impurity of n mold, Mn, Cr, Mo used as the impurity of p mold, etc. beforehand, and depositing Fe, these impregnation impurities permute by Fe atom, and also have the effectiveness which can form the epitaxial layer of quality beta-FeSi 2 doped with the sufficient controllability in n mold or p mold.
[0115] Furthermore, by heat-treating in piles Si substrate which deposited Fe with other Si substrates, Si substrate and solid phase reaction of both sides are produced, it is the form where the epitaxial layer of beta-FeSi 2 is embedded in Si layer of both sides, bonding of the two substrates is carried out, and Fe also has the effectiveness which can form the double hetero structure of Si/beta-FeSi 2 / Si and to say.

[Translation done.]

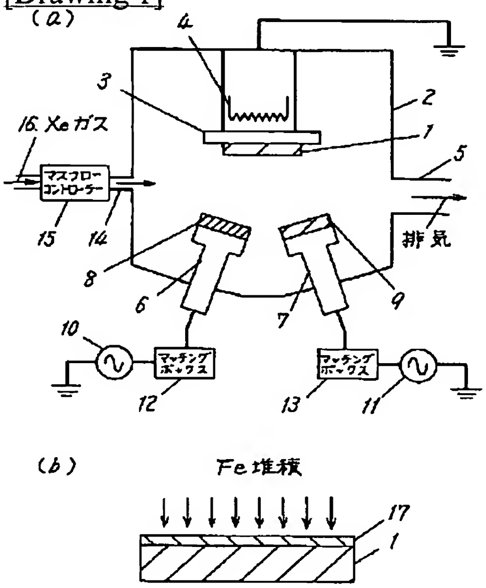
* NOTICES *

JPO and NCIPI are not responsible for any damages caused by the use of this translation.

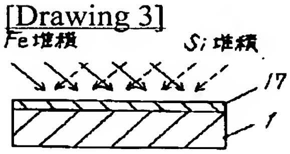
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

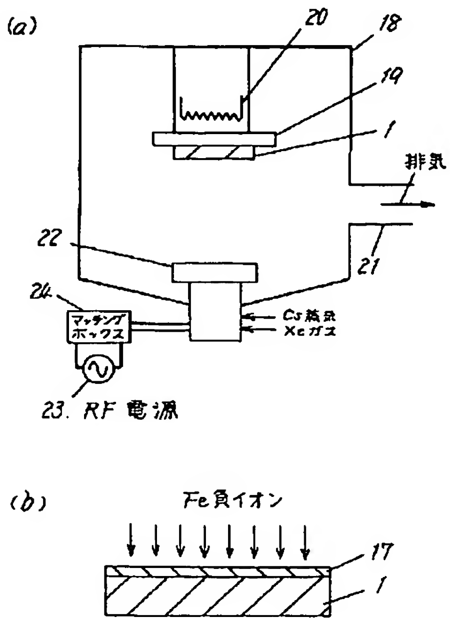
[Drawing 1]



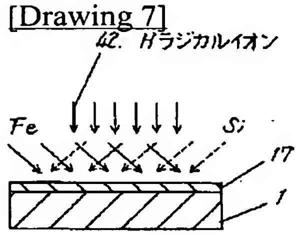
[Drawing 3]



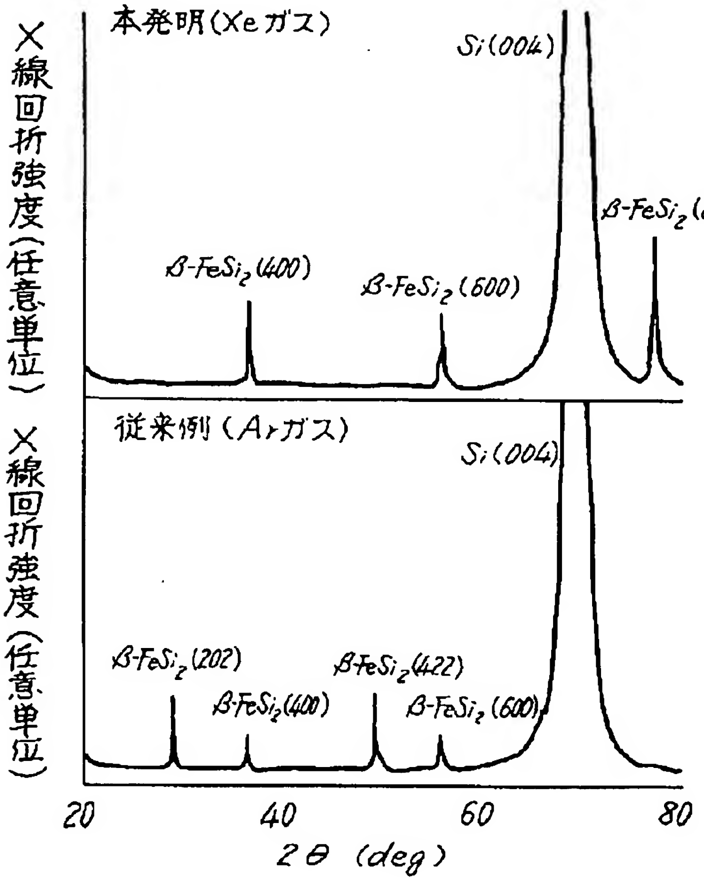
[Drawing 4]



[Drawing 7]

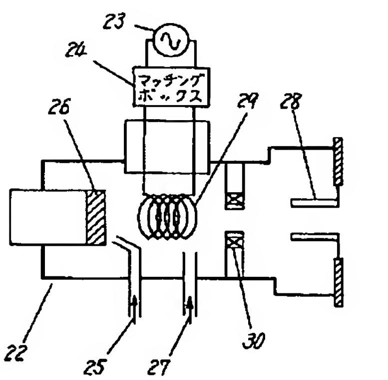


[Drawing 2]

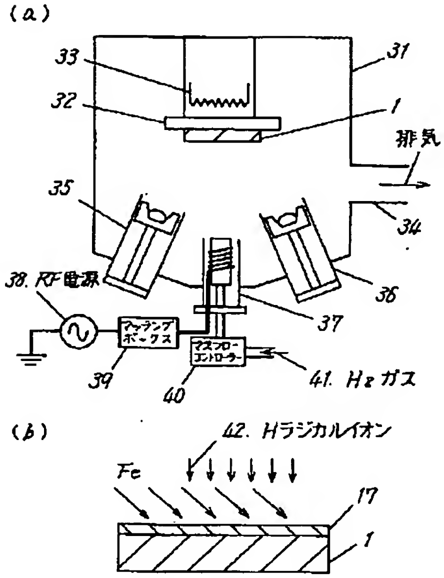


[Drawing 5]

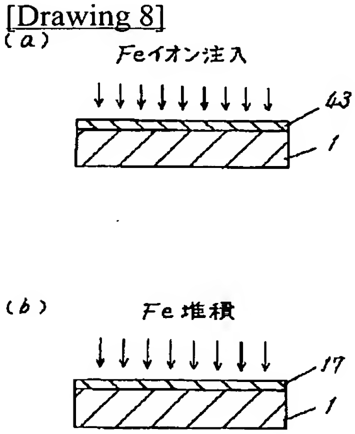
23 RF電源　29 高周波コイル
25 Cs蒸気　30 磁　石
27 Xeガス



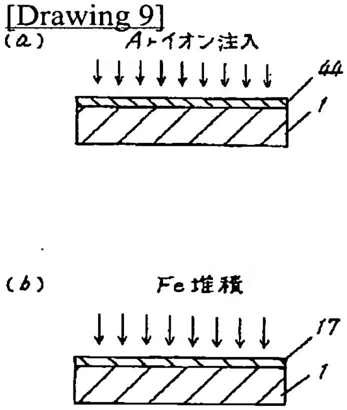
[Drawing 6]



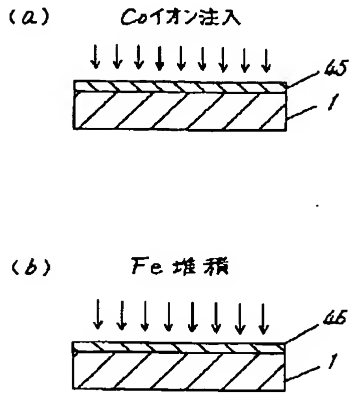
[Drawing 8]



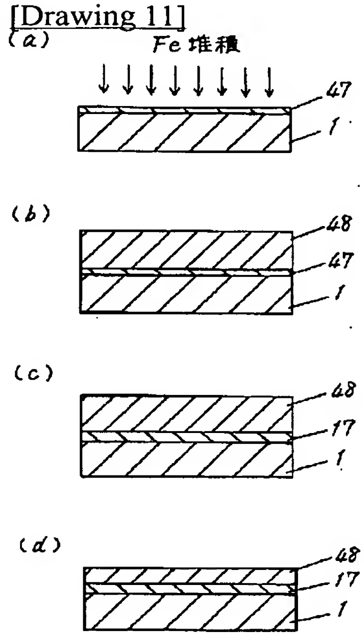
[Drawing 9]



[Drawing 10]



[Drawing 11]



[Translation done.]

This Page is Inserted by IFW Indexing and Scanning Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- [x] BLACK BORDERS
- [x] IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- [x] FADED TEXT OR DRAWING
- [ ] BLURRED OR ILLEGIBLE TEXT OR DRAWING
- [ ] SKEWED/SLANTED IMAGES
- [x] COLOR OR BLACK AND WHITE PHOTOGRAPHS
- [ ] GRAY SCALE DOCUMENTS
- [ ] LINES OR MARKS ON ORIGINAL DOCUMENT
- [ ] REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- [ ] OTHER: ______________________

IMAGES ARE BEST AVAILABLE COPY.
As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.